Department of Defense

High Performance Computing Modernization Program

High Performance Computing *and the* Test & Evaluation Community

Cray Henry, HPCMP

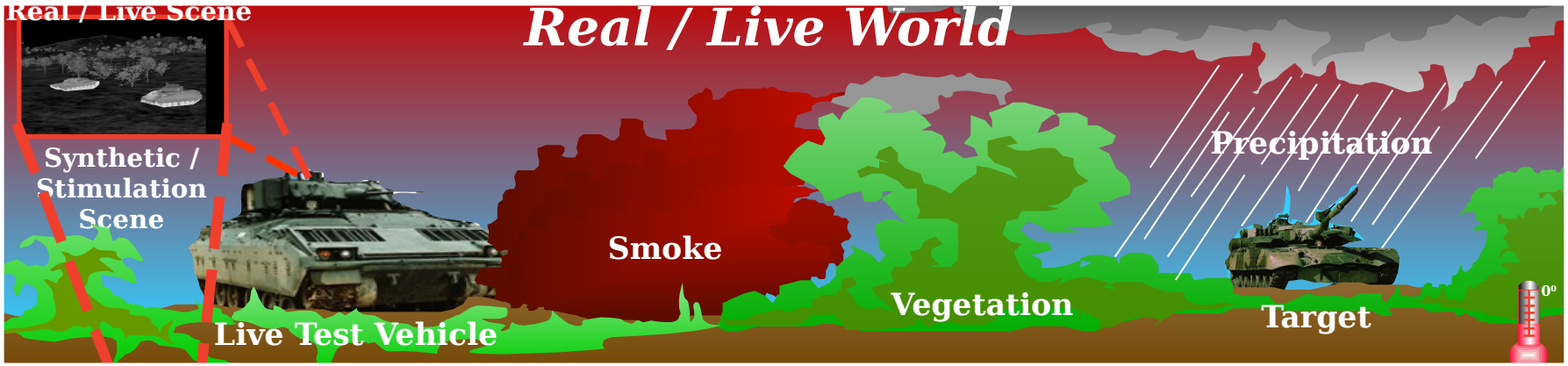
20th Annual NDIA Test & Evaluation Conference

March 2004

U.S. Army TECOM HPC Distributed Center

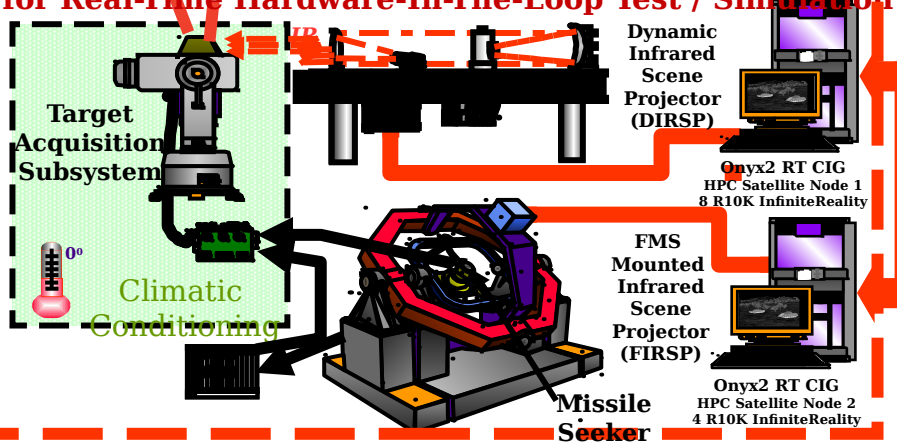
Located at the

Redstone Technical Test Center

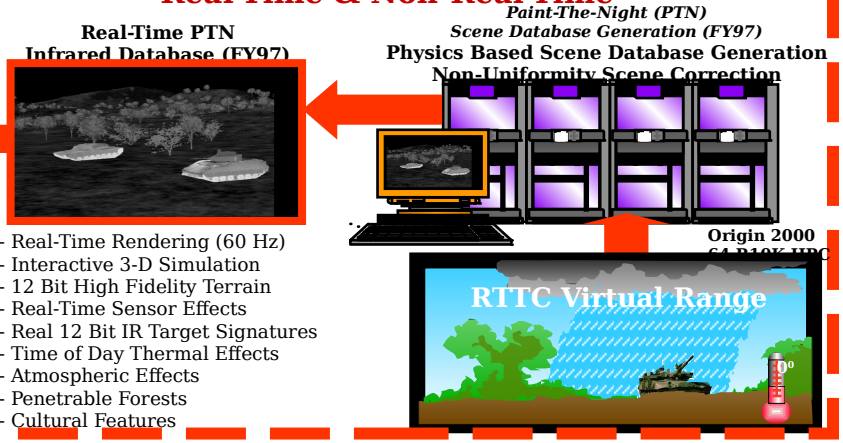


Synthetic / Stimulation World

Computer Image Generation
for Real-Time Hardware-In-The-Loop Test / Simulation



Scene Database Generation
Real-Time & Non-Real-Time



Paint-The-Night (PTN) Scene Simulation Utilized to Drive

Agenda

- Mission
- Program Resources
  - HPC Centers
  - SAS
  - DREN
- Example Projects
- How to Get Started
- Closing Remarks

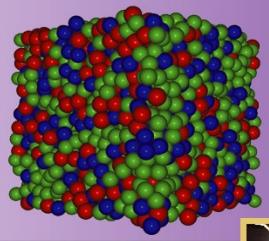
Mission

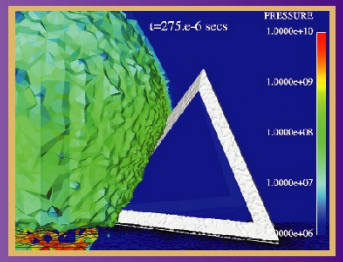
Deliver world-class commercial, high-end, high performance computational capability to the DoD's science and technology (S&T) and test and evaluation (T&E) communities, facilitating the rapid application of advanced technology into superior warfighting capabilities.

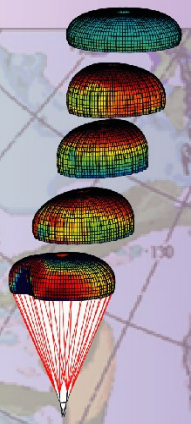
Vision

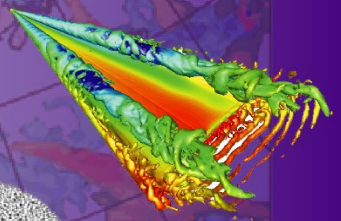
A pervasive culture existing among DoD's scientists and engineers where they routinely use advanced computational environments to solve the most demanding problems.

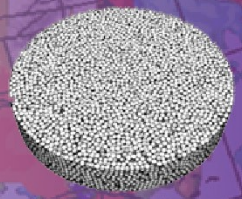
HPC Modernization Program

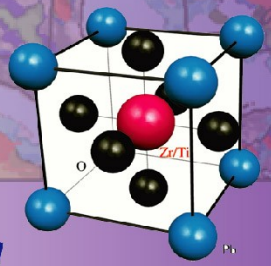


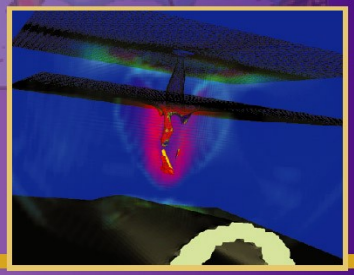


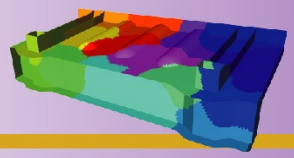








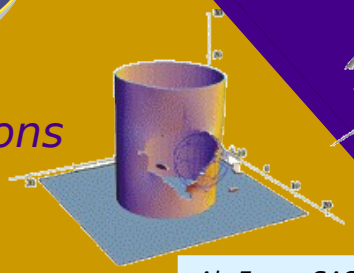




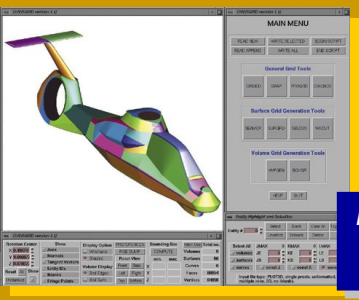
Tools for Discovery

HPC Modernization Program

Software Applications Support



CHSSI



PET

Warfighter Support

HPC Centers

Major Shared Resource Centers (MSRCs)
Distributed Centers (DCs)

Air Force HPC Centers
ASC MSRC
AEDC, AFRL/IF, AFWA, SIMAF, & MHPCC DCS
1,004 Users

Army HPC Centers
ARL & ERDC MSRC
AHPCRC, ATC, RTTC, SMDC, & WSMR DCs
1,366 Users

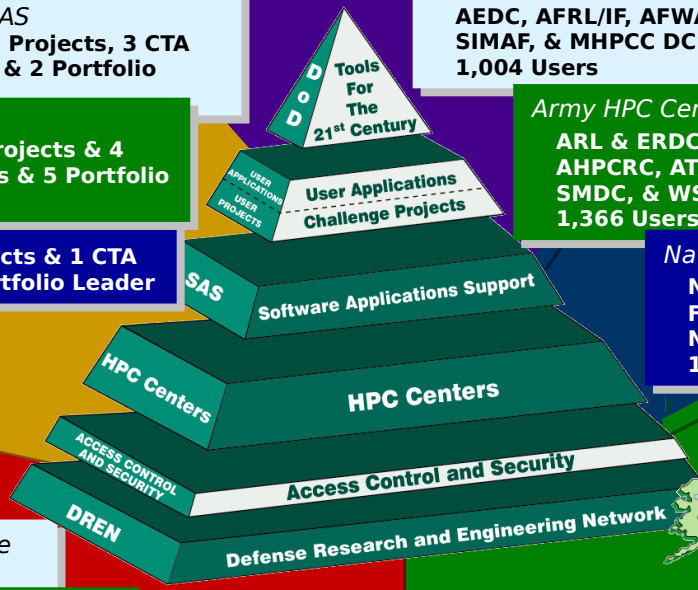
Navy HPC Centers
NAVO MSRC
FNMOC, SSCSD, NAWCAD & NRL DCs
1,354 Users

Defense Agencies
DARPA, DTRA, JNIC, JFCOM, MDA, & OTE
337 Users

Air Force SAS
12 CHSSI Projects, 3 CTA Leaders, & 2 Portfolio Leaders

Army SAS
10 CHSSI Projects & 4 CTA Leaders & 5 Portfolio Leaders

Navy SAS
11 CHSSI Projects & 1 CTA Leader & 1 Portfolio Leader



Resource Mgmt

Air Force Challenge
7 Projects

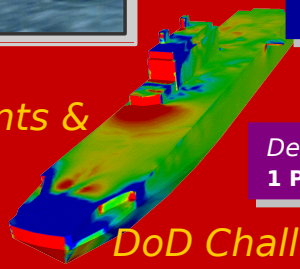
Army Challenge
13 Projects

Navy Challenge
11 Projects

Joint Challenge
2 Projects

Defense Agencies Challenge
1 Project

Requirements & Allocations



DoD Challenges

DREN

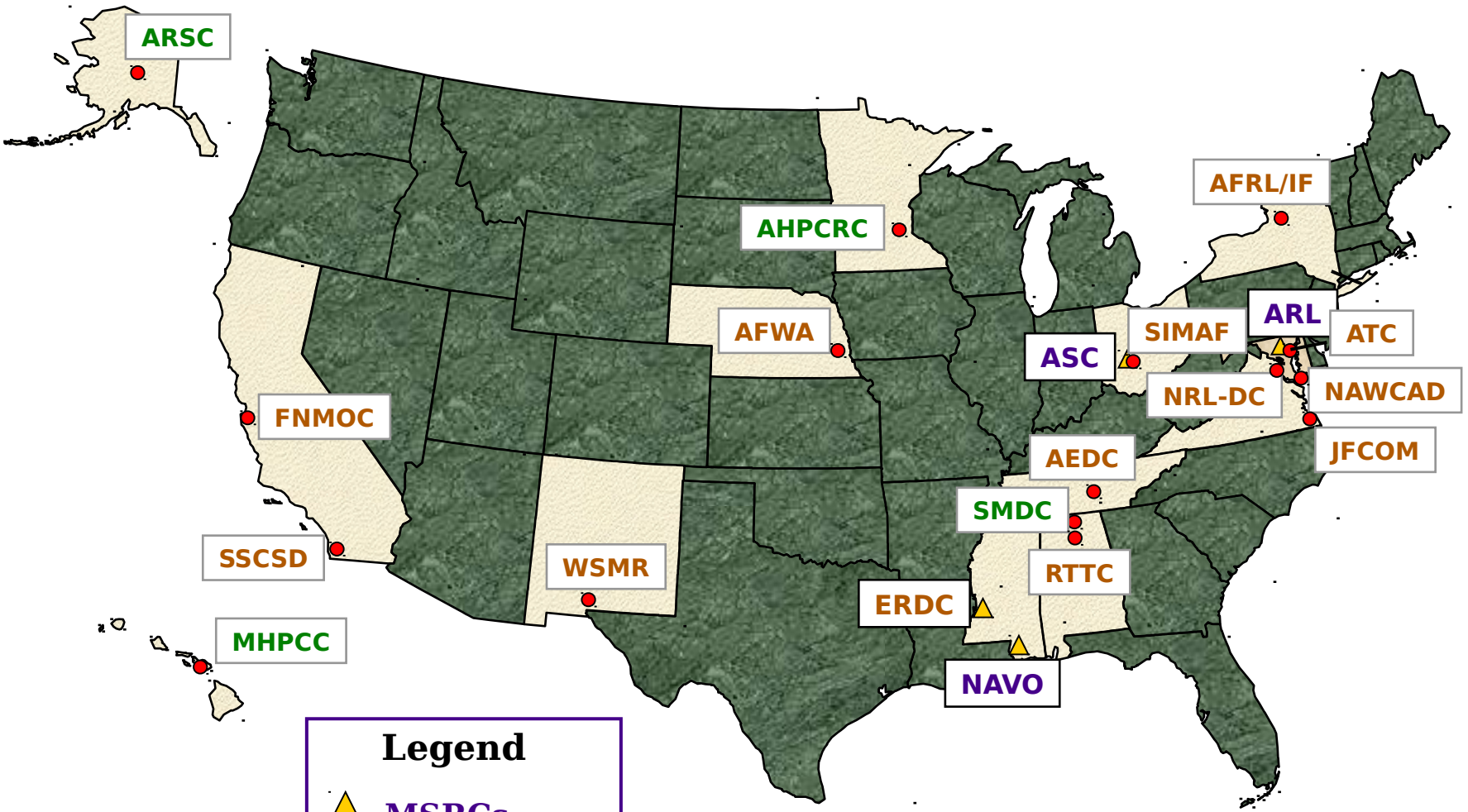
Air Force DREN
21 Sites

Army DREN
28 Sites

Navy DREN
18 Sites

Defense Agencies DREN
6 Sites

HPCMP Centers



Major Shared Resource Centers (MSRCs)

- Major Shared Resource Centers provide…
- Complete networked HPC environments
- World-class HPC compute engines
- High-end data analysis & scientific visualization support
- Massive hierarchical storage
- Proactive and in-depth user support/computational technology area expertise

…to nation-wide user communities

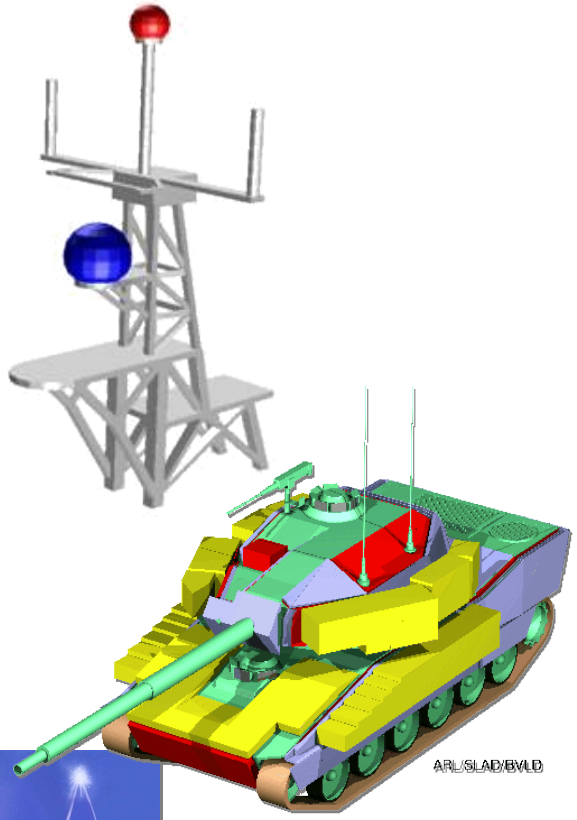
FY 04 DC Awards

Site	Project Title	Service
RTTC	Advanced Dynamic Scene Projection	Army
FNMOC/AFWA	Joint Operational Test Bed for the Weather Research and Forecast Modeling Framework	AF/Navy
JFCOM	Experimentation Environment	Joint
SSCSD	Virtual Electronic Battlefield	Navy
ATC	Real Time Data Warehousing, On-Line Analytical Processing, and Data Mining Techniques	Army

Distributed Centers

- **Allocated Distributed Centers (ADC)**
  - ADCs support the annual service/agency project allocation and/or challenge project allocation process by providing reserved compute resources

    … Large systems supporting a few high priority projects

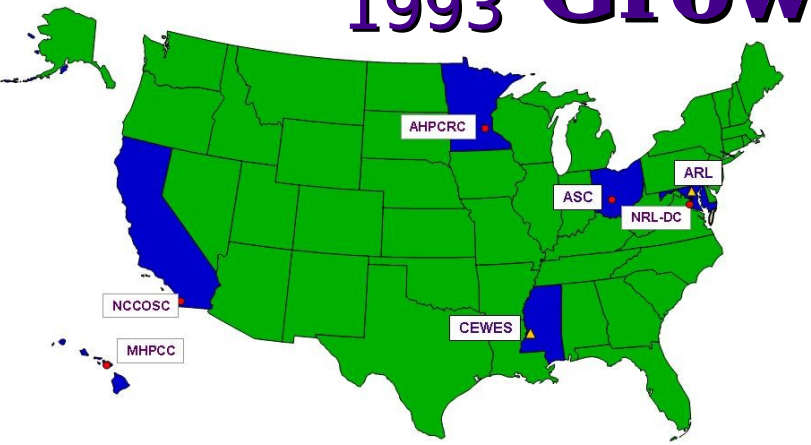


- **Dedicated Distributed Centers (DDC)**
  - DDCs support a dedicated project or projects for which each independent DDC was awarded an HPC system

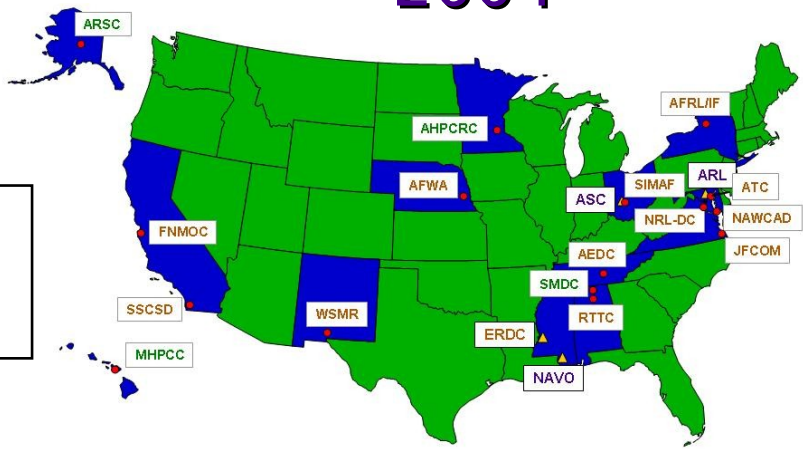
    … Moderate systems supporting dedicated local needs

HPC Centers Growth

1993

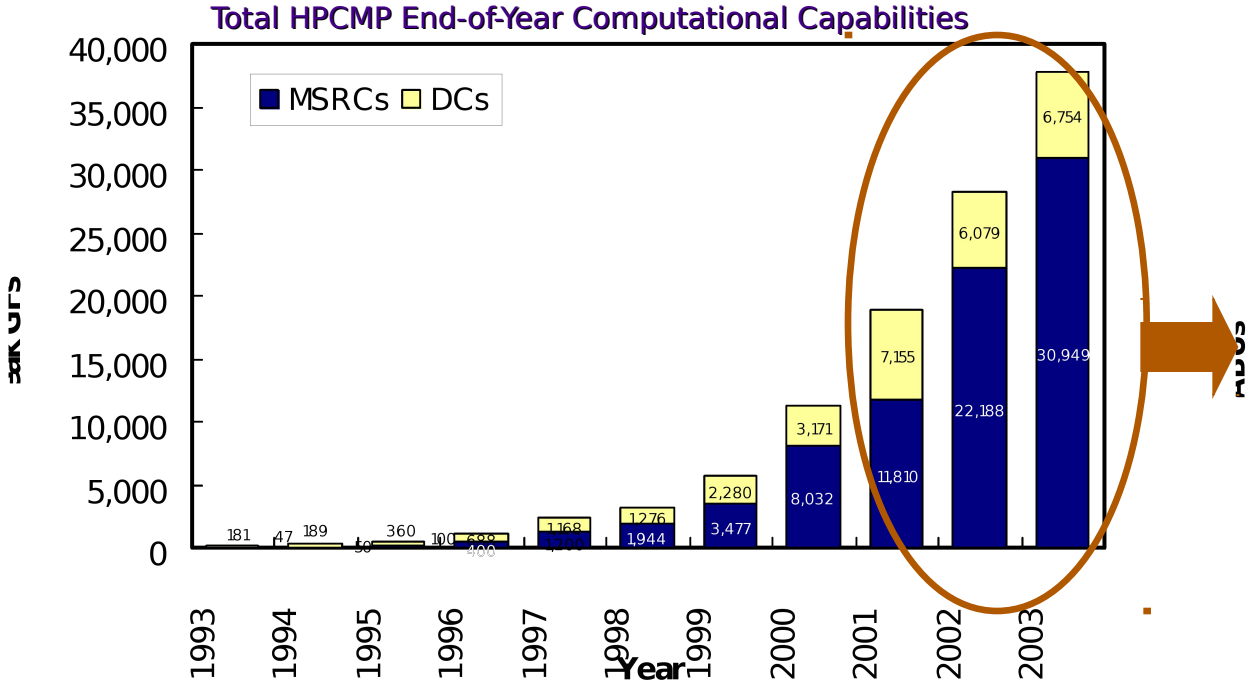


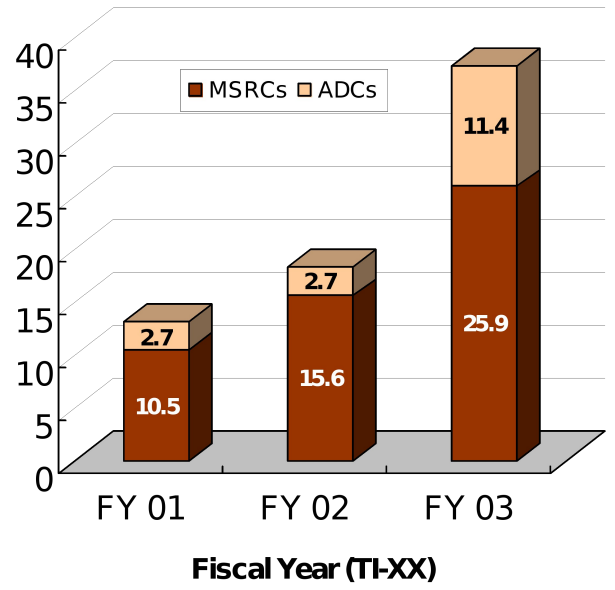
2004



Legend

- MSRCs
- ADCs and DDCs





HPCMP Systems (MSRCs)

HPC Center	System	Processors
ARL	IBM P3	1,024 PEs
	SGI Origin 3000	256 PEs
		512 PEs
	IBM P4	704 PEs
		128 PEs
	Linux Networx Cluster	256 PEs
ASC	Compaq SC-45	836 PEs
	IBM P3	528 PEs
	COMPAQ SC-40	64 PEs
	SGI Origin 3900	2,048 PEs
	SGI Origin 3900	128 PEs
	IBM P4	32 PEs
ERDC	Compaq SC-40	512 PEs
	Compaq SC-45	512 PEs
	SGI Origin 3000	512 PEs
	Cray T3E	1,888 PEs
	SGI Origin 3900	1,024 PEs
	Cray X1	64 PEs
NAVO	IBM P4	1,408 PEs
	IBM P3	1,336 PEs
	SV1	64 PEs

FY 01 and earlie
FY 02
FY 03

HPCMP Systems (ADCs)

HPC Center	System	Processors
AHPCRC	Cray T3E	1,088 PEs
	Cray X1, LC	128 PEs
ARSC	Cray T3E	272 PEs
	Cray SV1	32 PEs
	IBM P3	200 PEs
	IBM P4	800 PEs
	Cray X1	128 PEs
MHPCC	IBM P3 (2)	716/320 PEs
	IBM Netfinity Cluster	512 PEs
	IBM P4	320 PEs
SMDC	SGI Origins	1,056 PEs
	Cray SV-1	32 PEs
	W.S. Cluster	64 PEs
	IBM e1300 Cluster	256 PEs
	Linux Cluster	256 PEs
	IBM P4	32 PEs

FY 01 and earlie
FY 02
FY 03

HPCMP Dedicated Distributed Centers

Location	System	Description *(Processors/Memory)*	Capacity *(Peak GFs)*
AEDC	HP Superdome	32/**32 GB**	70
Arnold AFB, TN	IBM Itanium Cluster	16/**32 GB**	51
	IBM Regatta P4	64/**64 GB**	333
	Pentium Cluster	8/**8 GB**	70
AFRL/IF	Sky HPC-1	384/**26 GB**	640
Rome, NY			
		30/**4 GB**	24
FNMOC	SGI Origin3900		
Monterey, CA			
NAWCAD	SGI Origin 2000	30/**4 GB**	24
Patuxent River, MD	SGI Origin 3900	64/**24 GB**	90

As of: June 2003

HPCMP Dedicated Distributed Centers

Location	System	Description *(Processors/Memory)*	Capacity *(Peak GFs)*
NRL	SUN Sunfire 6800	32/**32 GB**	115
Washington, DC	Cray MTA	40/**160 GB**	24
	SGI Altix	128/**128 GB**	512
	SGI Origin 3000	128/**128 GB**	128
SIMAF			
Wright-Patterson AFB	SGI Origin 3900	24/**24 GB**	34
	Beowulf Cluster		
WSMR	Linux Networx	64/**64 GB**	392
Whites Sands, NM			

As of: June 2003

DDC Projects

Air Force Research Laboratory, Information Directorate

- Real-time multi-sensor data fusion processing supporting command, control, communications, computers, and intelligence (C4I) programs
- CTAs - signal and image processing, forces modeling and simulation/C4I, integrated modeling and test environments, computational electromagnetics and acoustics

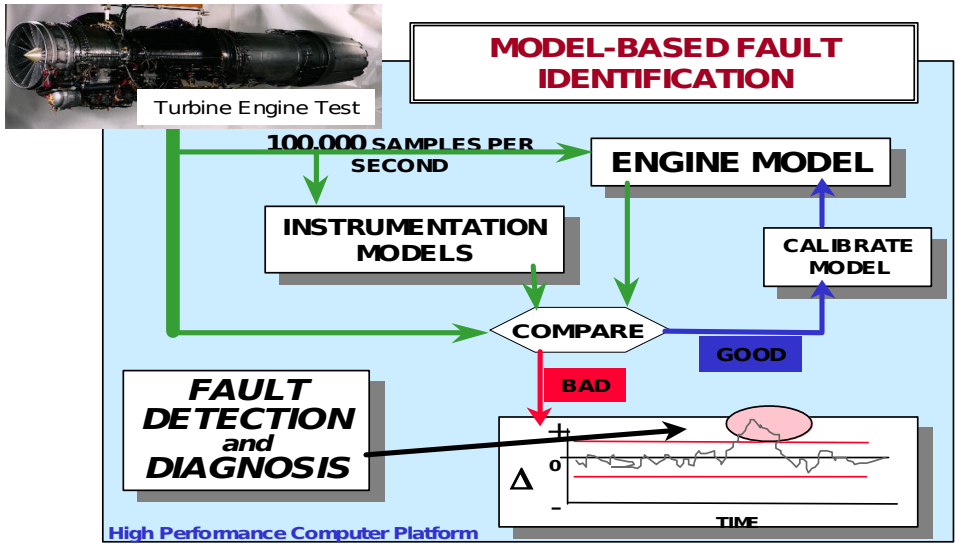
Arnold Engineering Development Center

- Data acquisition and simulation of aircraft, missile and space systems and subsystems for test and evaluation
- CTAs - computational fluid dynamics, integrated modeling and test environments

Model-Based Test Data Validation (MBTDV)

M.A. Chappel, D.J. Malloy, and B.K. Feather,
AEDC/Aerospace Testing Alliance, Arnold AFB, TN;
Sponsor: Air Force

- Automation of data validation processes requires a broad range of computational tools that emulate standard engineering analysis processes
- Objective is to develop a suite of scalable Signal Characterization Models and Component Level Models with real-time data fault detection, diagnosis, and correction capability to support aeropropulsion system performance testing
- Applied to development testing for turbine engines for the F/A-18 E/F, the F-22, and the Advance Turbine Engine Gas Generator
- MBTDV models have identified



MBTDV has resulted in a reduction in re-test occurences caused by post-test discoveries of invalid data; MBTDV has the potential to automate data validation process for a wide range of testing

DDC Projects *(continued)*

Fleet Numerical Meteorology and Oceanography Center

- Real-time meterological predictions
- **CTAs -** climate, weather, ocean modeling and simulation

Naval Air Warfare Center Aircraft Division

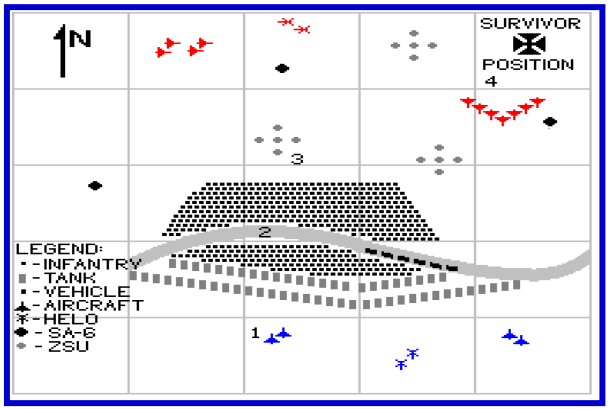
- **Real-time hardware-in-the-loop avionics and weapon systems simulations for test and evaluation**
- **CTAs -** forces modeling and simulation , computational electromagnetics and acoustics, **integrated modeling and test environments**

Joint Combat Search and Rescue

Evaluate Multi-Service CSAR doctrine and numerous interoperabil issues. Aviation Test Bed (AVTB, Ft. Rucker), TACCSF, MCAS Mira Airborne Electronic Warfare Wing (AEWW), ACETEF

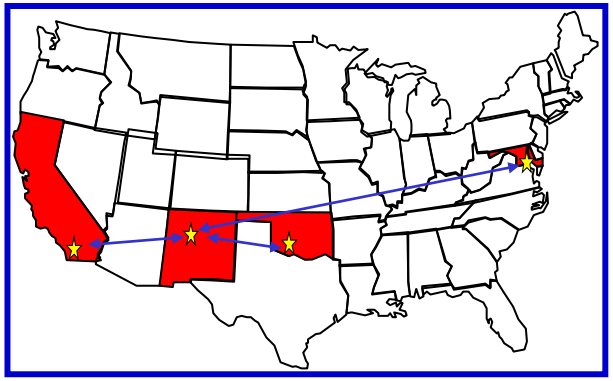
Computation Requirements:

28 R10000 Processors
8 GB Memory
2 Infinite Reality Graphics Pipes
Scramnet (Shared Common Random Access Memory Network)



Benefits To Warfighter:

JCSAR provided a method of training the warfighter in joint exercises for CSAR (Combat Search and Rescue) activities. This type of exercise solves the problems encountered in activities, such as Kosovo, where a coordinated effort was not achieved and gives a higher probability of mission success.



HPC Solved The Problem:

HPC was used to provide seamless visuals for this Distributed Exercise integration by providing correlated images for two man-in-the-loop F/A-18 C/D players. It enabled the testers to incorporate correct threat models and missile flyouts.

JSF Virtual Strike Warfare Environment

VSWE-5 was designed to operate around the warfighting decisions made by groups of pilots from several air arms. These aviators were given the opportunity to fly simulated strike missions with computer-generated JSFs in a highly detailed, tactically challenging, synthetic environment that represented the threat environment that they would be likely to encounter in the next century.

Computation Requirements:

36 R10000 Processors
16 GB Memory
4 Infinite Reality Graphics Pipes
Scramnet (Shared Common Random

HPC Solving The Problem:

HPC was used to process a large visual database into appropriate textures and images in real time. This provided a realistic scene that was then correlated with the Air Force mission systems distributed simulation. Improved real-time re

Benefits To The Warfighter:

This improved performance provided the warfighters and planners a more realistic environment to which to rehearse the planned missions. This, in turn, gave the warfighters additional means to make valued judgements with respect to current JSF concepts under technical consideration

DDC Projects *(continued)*

Naval Research Laboratory, DC

- **Early access, development and testing of new innovative computing and communications architectures**
- **CTAs - climate, weather and ocean modeling, computational fluid dynamics, computational chemistry and materials science**

Simulations & Analysis Facility

- **Secure, high-fidelity, real-time virtual simulation for development, testing, training, and operation of air vehicle systems**
- **CTAs - forces modeling and simulation,**

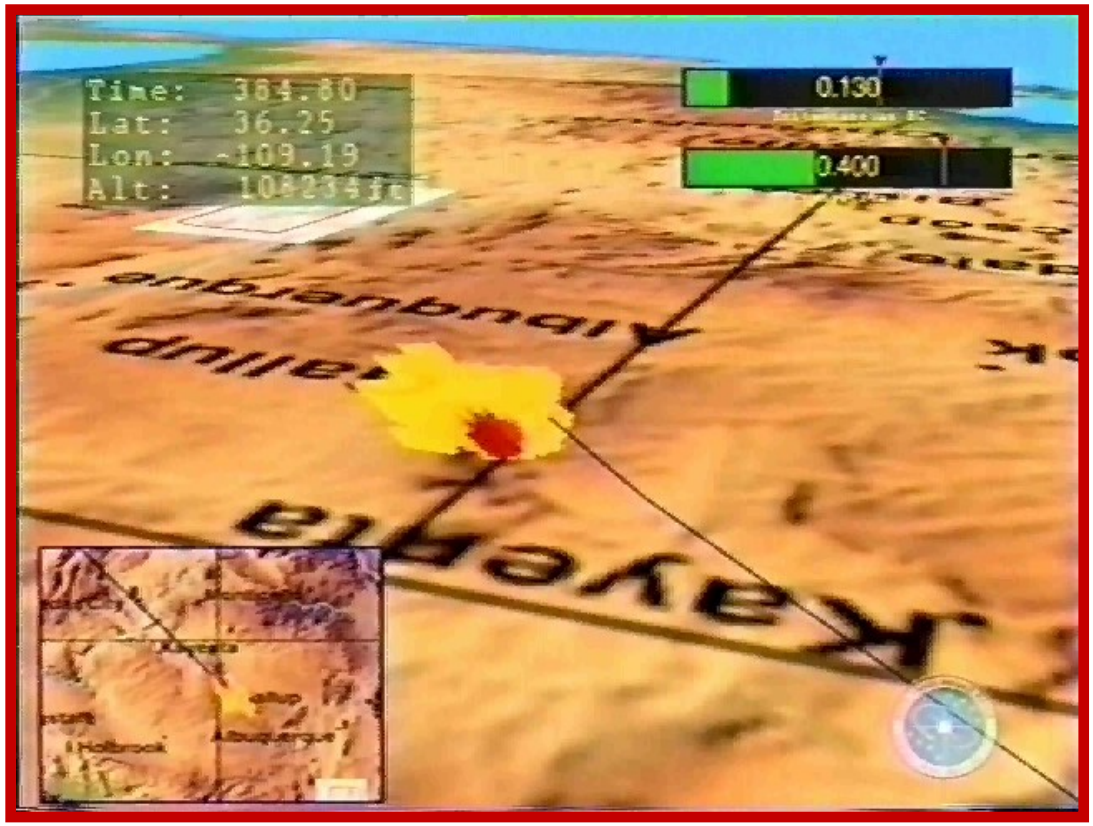
DDC Projects *(continued)*

White Sands Missile Range

- **Real-time test and evaluation of data imaging for aerial objects**
- **CTAs - signal image processing, and forces modeling and simulation**

Pre-Mission Planning
Flight Safety Analysis

- Risk and hazard visualization
- Population density visualization
- Trajectory, corridor, overshoot planning
- System has supported several programs including NASA's X-34 project
- System delivered to Range



Software Applications Support

- **Common High Performance Computing Software Support Initiative (CHSSI)**
  - **Supports development of common, efficient HPC applications**
- **Programming Environment & Training**
  - **Enhance user productivity**
- **Software Protection**
  - **Develop best techniques for the protection of HPC applications**

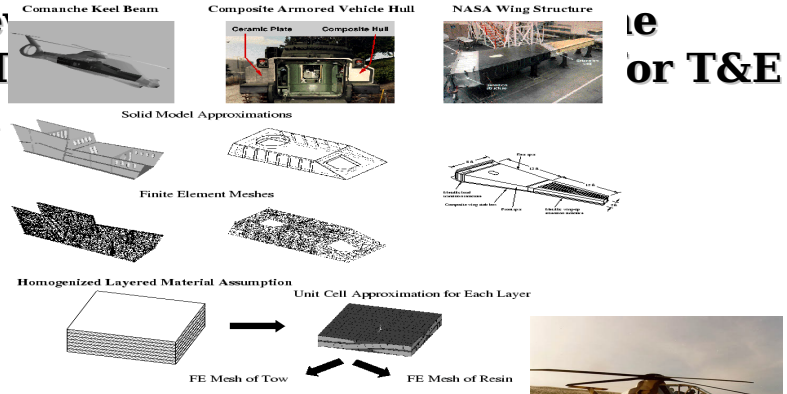
Computational Technology Areas (CTAs)

Computational Technology Area	DoD Users Primary	DoD Users Total
Computational Structural Mechanics (CSM)	528	1,019
Computational Fluid Dynamics (CFD)	1,154	1,612
Computational Chemistry and Materials Science (CCM)	243	593
Computational Electromagnetics and Acoustics (CEA)	295	575
Climate/Weather/Ocean Modeling and Simulation (CWO)	284	521
Signal/Image Processing (SIP)	239	815
Forces Modeling and Simulation (FMS)/C4I	527	913
Environmental Quality Modeling and Simulation (EQM)	120	295
Computational Electronics and Nanoelectronics (CEN)	35	135
Integrated Modeling and Test Environments (IMT)	994	1,201
Other	63	219

Data Source: HPCMP Requirements Analysis, 2004

CHSSI/PET Contributions to T&E

- **FMS-2 Simulation Leveraged Acquisition Test and Evaluation:** Parallel processing simulation techniques for use in the acquisition test and evaluation
- **FMS-7 Parallelization of the Joint Interim Mission Model:** Enhance the test and evaluation activities to improve productivity, precisely assess the performance of high technology warfare systems, reduce/eliminate limitations of scope in operationally rele… …e RDT… …or T&E and …

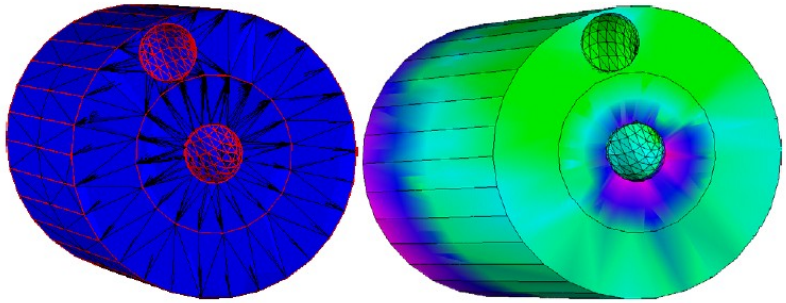


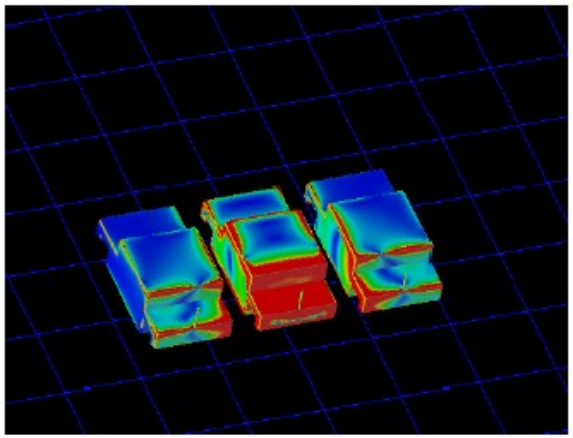
- **Integrated Modeling and Test Environments (IMT)** addresses the application of integrated modeling and simulation tools and techniques with live tests and hardware-in-the-loop simulations for the testing and evaluation of DoD weapon components, subsystems, and systems in virtual and composite virtual-real environments

HPC Technologies Transferred by PET

Computational Technology Applications and Algorithms

- **Virtual Testing of Electromagnetic Effects on Munitions**
  - Single-frequency visualization of the surface current of M100 detonator illuminated by an electromagnetic field





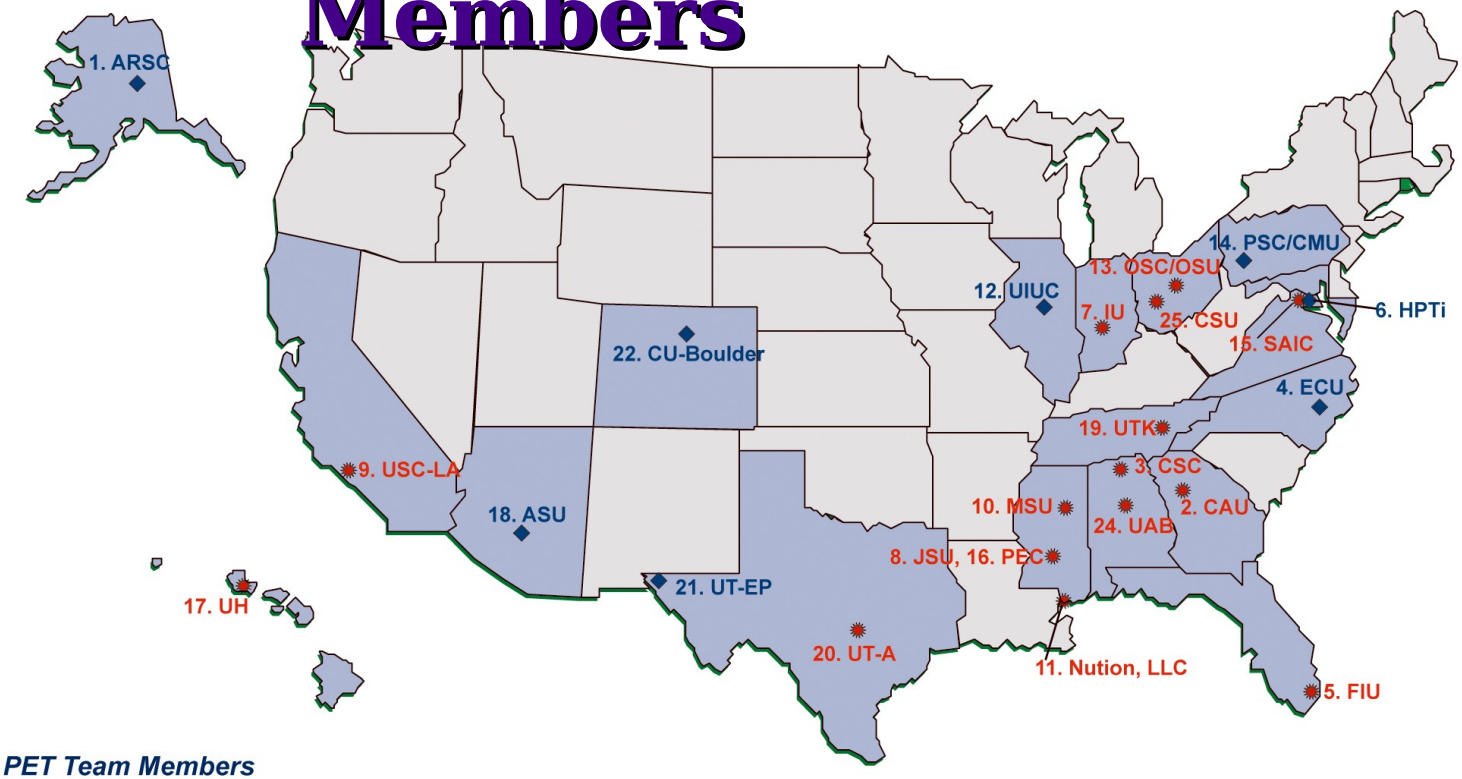
- **Electronic Battlefield Information Exploration**
  - Surface currents extracted from FDTD simulation

PET Success
SEDRIS Parallelization

- PET developed the SEDRIS Parallel and Distributed Interface (SPDI). SEDRIS is a technology for the loss-less and unambiguous representation and exchange of environmental data, such as terrain elevation, buildings, and weather. SPDI provides a manager/worker paradigm to divide and manage labor across multiple processes and handles both general and SEDRIS specific inter-process communication. **This tool is being used on database development for the Army's CCTT where it has reduced test execution times from days to hours.** The military simulation co[illegible]ed SPDI by virtue of fun[illegible]oment based on this PET EMS

Core Effort in EMS

PET Team Members



PET Team Members

1. Arctic Region Supercomputing Center, Fairbanks, AK
2. Clark Atlanta University*, Atlanta, GA
3. Computer Sciences Corporation, Huntsville, AL
4. East Carolina University, Greenville, NC
5. Florida International University*, Miami, FL
6. High Performance Technologies, Inc., Arlington, VA
7. Indiana University, Bloomington, IN
8. Jackson State University*, Jackson, MS
9. University of Southern California, Los Angeles, CA
10. Mississippi State University, Mississippi State, MS
11. Nution, LLC, Bay St. Louis, MS
12. University of Illinois, Urbana-Champaign, IL
13. Ohio Supercomputer Center/The Ohio State University, Columbus, OH
14. Pittsburgh Supercomputing Center/Carnegie-Mellon University, Pittsburgh, PA
15. Science Applications International Corporation, McLean, VA
16. PEC Solutions, Inc., Jackson, MS
17. University of Hawaii*, Honolulu, HI
18. Arizona State University, Tempe, AZ
19. University of Tennessee, Knoxville, TN
20. University of Texas, Austin, TX
21. University of Texas*, El Paso, TX
22. University of Colorado, Boulder, CO
24. University of Alabama, Birmingham, AL
25. Central State University*, Wilberforce OH

** denotes Minority Serving Institution (MSI)*

Legend

- HPTi Team
- MOS University Consortium

Defense Research & Engineering Network (DREN)

NAVAIR

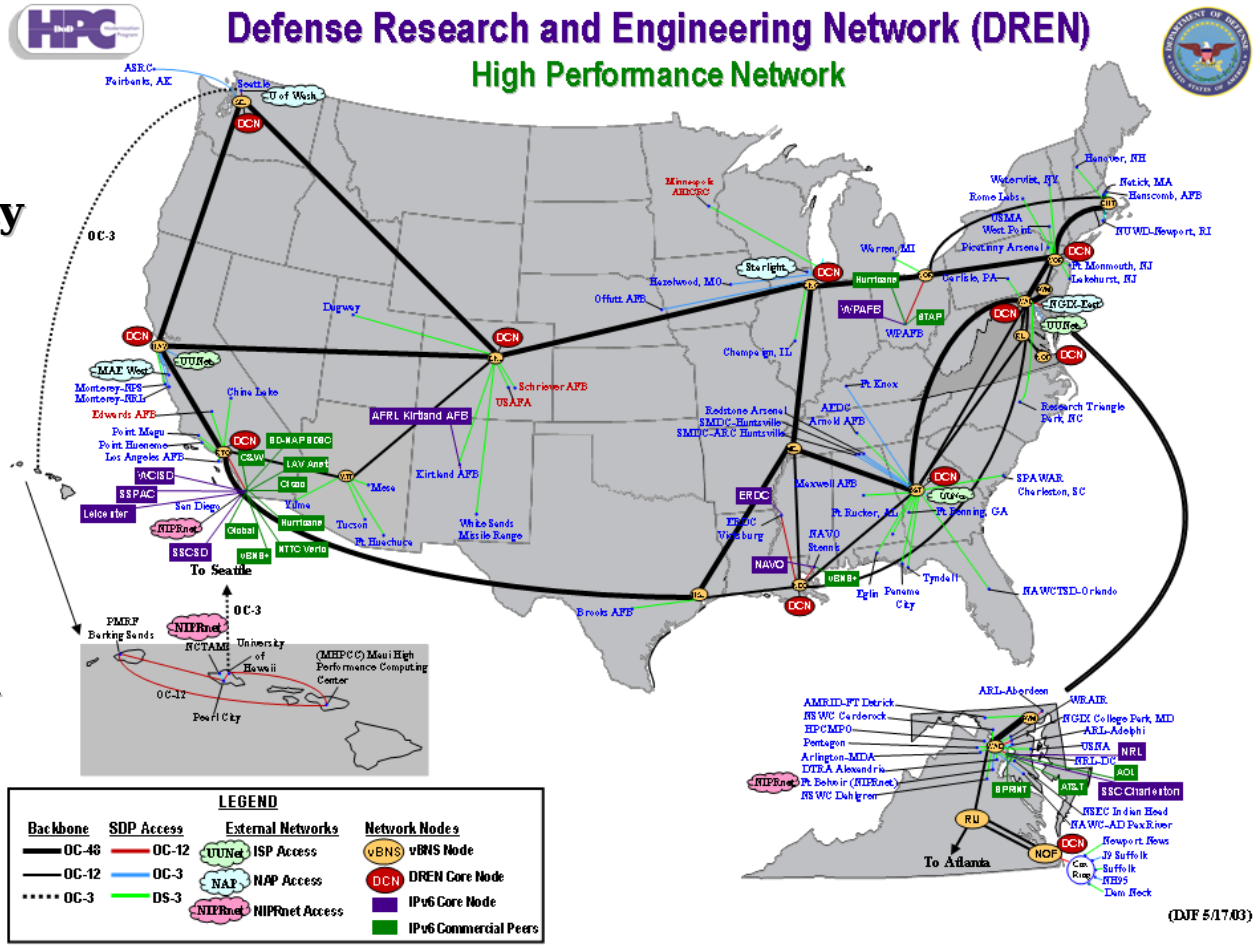
Pre & Post Flight Monte Carlo Simulation For DT-IIIC/OTIIIA

- **RAM Combined Simulation With Dynamic Scene Generation Used To Support Pre-Flight Simulation & Analysis For FY03 DT-IIIC/OT-IIIA Test Series**
  - **50-100 Case Monte-Carlo Simulations For Multiple Flight & Target Scenarios**
  - **4 SGI ONYX2 Multi-Processor Computers (IBAR @ China Lake)**
    - **Peak Processor Allocation => 72 (12 Instances Of Ram Combined Simulation @ 6 processors each)**
    - **Average Processor Allocation => 36**
    - **Processes Split Over The 4 SGI ONYX2 Computers (Shared Resources)**
  - **SDREN Used For Remote Personnel At Patuxent River**
  - **Analysis Using MATLAB Split Between Personal Computers (PC) and SGI**
- **DT-IIIC/OT-IIIA Post-Flight Simulation & Analysis**
  - **Analysis using MATLAB Primarily On Personal Computers (PC)**
  - **Post-Flight Simulation On SGI ONYX2 (IBAR @ China Lake)**
    - **Estimated Peak Processor Allocation => 12**

DoD HPC Modernization Program

DREN IPv6 Pilot

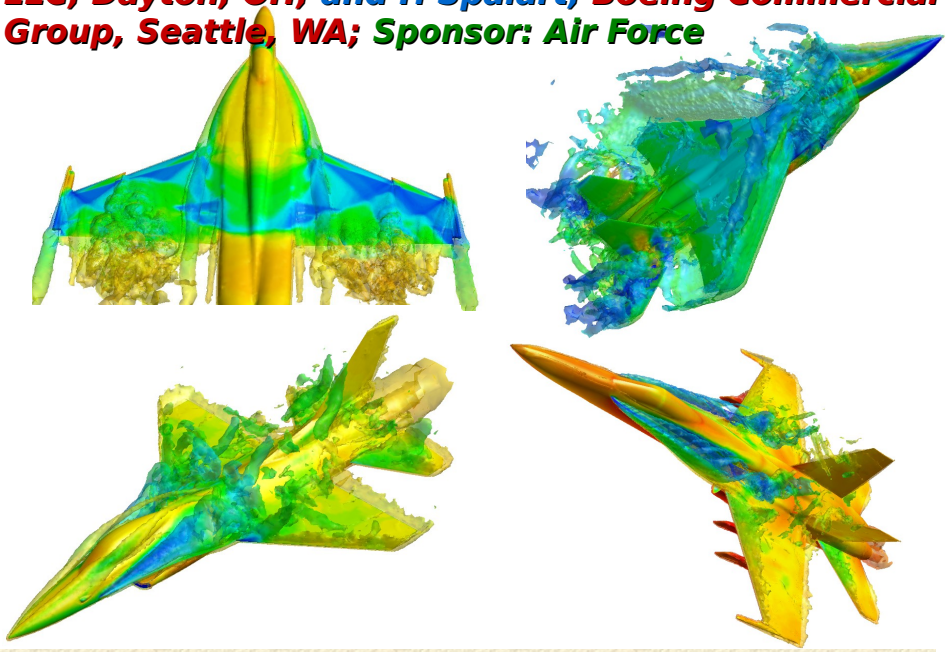
- One of only 2 FY04 DoD pilot networks
- Enables nation-wide IPv4/IPv6 connectivity across S&T community
- Supports DoD IPv6 demonstrations and tests, such as Joint Interoperability Test Command MoonV6, DICE
- Supports DoD CIO and DoD working group planning efforts
- Supports DISA IPv6 JPO in technical and standards activities
- Disseminates IPv6 information via web, briefings, conferences



Multidisciplinary Applications of Detached-Eddy Simulations of Separated Flows at High Reynolds Numbers

J. Forsythe, S. Morton, and R. Cummings, USAFA, Colorado Springs, CO; K. Squires, Arizona State University, Tempe, AZ; K. Wurtzler, Cobalt Solutions, LLC, Dayton, OH; and P. Spalart, Boeing Commercial Group, Seattle, WA; Sponsor: Air Force

- **Predict abrupt wing stall on F/A-18E in a wind-up turn; predict F-15E aircraft spin entry; predict aero-elastic tail buffet on the F-18C; and predict the aero-elastic limit cycle oscillation on the F-16**
- **Computations will be performed using Cobalt and the Detached-Eddy Simulation (DES) turbulence models, rigid body motion, a multiple degree of freedom model, and deforming meshes**
- **Unsteady separated flows with moving and deforming grids will require increased computation time per timestep and cost is expected**



Successful predictions of separated flows will decrease flight test costs and risks as well as discovering design flaws earlier so they can be corrected before the first test vehicle is manufactured

DoD Counter Terrorism Technology

- Development of a thermobaric weapon to defeat terrorists in tunnels
  - Assess performance, demonstrate effectiveness
  - Pre-test predictions, post-test analyses
- CENTCOM/EUCOM Customers
- 2 month accelerated effort

Charles Needham, John Perry, Terry Caipen, and Joe Crepeau, ARA, Albuquerque NM; Sponsor: DTRA

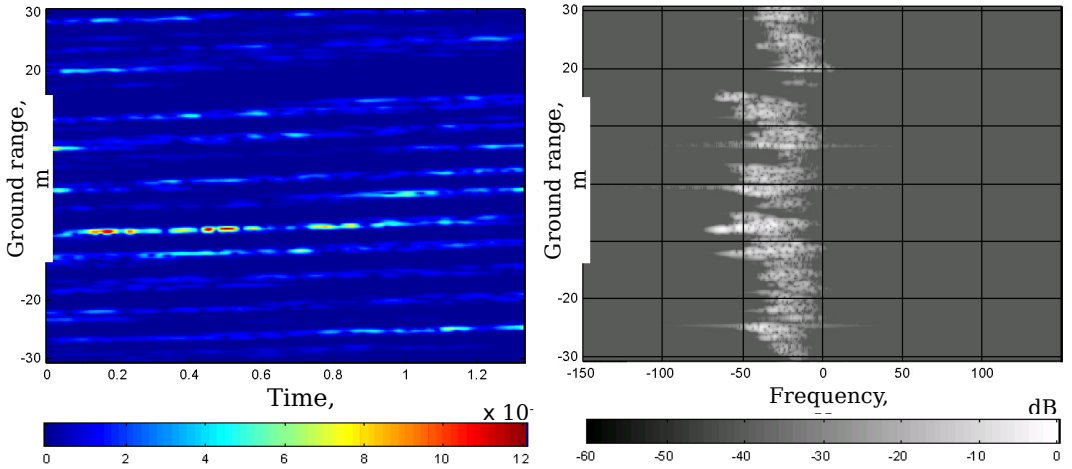
"Without your support we [illegible] provide the analytical support to this extremely fast paced project."

Support in designing a thermobaric explosive weapon with improved lethality against underground facilities

Simulation of Coherent Radar Backscatter from Dynamic Sea Surfaces

J. Toporkov, M. Sletten, S. Chubb, J. Heyer, and B. Gover, NRL, Washington, DC; R. Leighton, Veridian Corporation, Arlington, VA; and J. Duncan, University of Maryland, College Park, MD; Sponsor: Navy

- **Develop a high-fidelity numerical model of the dynamic sea backscatter process that can be used to optimize and predict the performance of high-range-resolution radar systems, and that can benchmark more approximate (less computationally-intensive) simulations**
- **Use state-of-the-art numerical simulations to address the electromagnetic and hydrodynamic aspects of the ocean backscatter problem**
- **Need for high spatial resolution requires calculation of the backscatter at thousands of frequencies, while the need for Doppler**



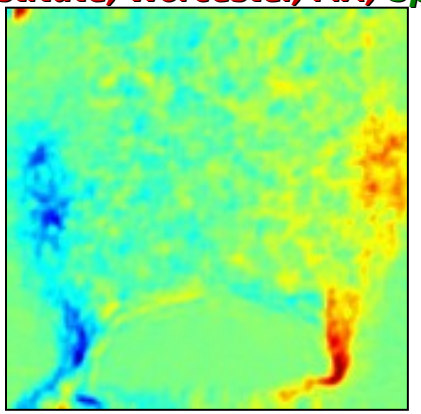
Range-resolved HH backscattering from a dynamic ocean-like surface at 5° grazing: range-time display (left) and range-Doppler display (right).

Simulations can be used to test advanced radar signal processing algorithms to detect VLO targets, assess the capability of threat systems to detect and track US platforms or notional next generation design concepts, and to synthetically generate sea clutter to support hardware-in-the-loop test and evaluation

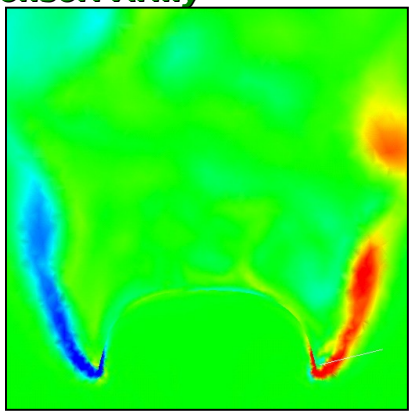
Airdrop System Modeling for the 21st Century Airborne Warrior

- Conduct simulations and validations of the Advanced Tactical Parachute System's response to real-world environmental conditions
- Apply improved coupling schemes between CFD (fluid) and CSD (parachute structure) for more robust FSI simulation strategy
- Refined meshes, jump in timesteps, parachute fluid structure interactions, complex production simulations for large periods on real time will be used
- Inclusion of special

R. Benney, SBCCOM, Natick, MA; K. Stein, Bethel College, St. Paul, MN; T. Tezduyar, Rice University, Houston, TX; M. Accorsi, University of Connecticut, Storrs, CN; and H. Johari, Worcester Polytechnic Institute, Worcester, MA; Sponsor: Army



Experimental vorticity measurements (from PIV data) performed under ARO grant



Vorticity data from FSI simulation

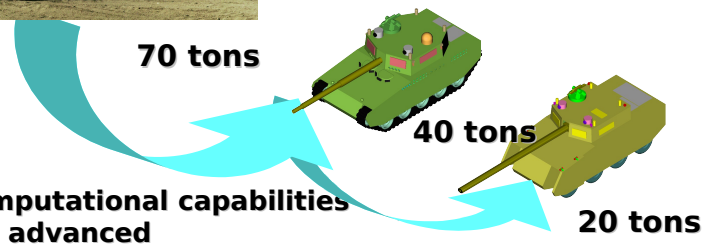
Minimize feasibility testing of new systems, assist in determining the capabilities of all systems and reduce the life cycle cost of all future DoD Airdrop Systems

Modeling Complex Projectile-Target Interactions II

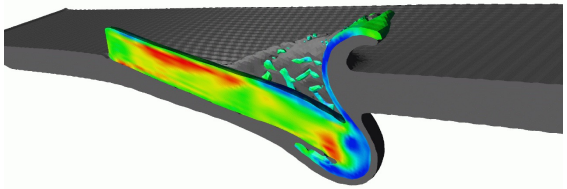
K. Kimsey and D. Kleponis, ARL, Aberdeen Proving Ground, MD; Sponsor: Army

- Combine large-scale simulations with ballistic tests to enhance the survivability and lethality of ground combat systems
- Proper treatment of the mechanics and physics of projectile-target interactions for combat vehicles requires the ability to efficiently perform mega-cell problems in reasonable times as opposed to months
- CTH code models problems in solid

Future Combat Systems (FCS) require lighter combat systems and more lethal munitions



Exploit computational capabilities to develop advanced armor/armaments technologies

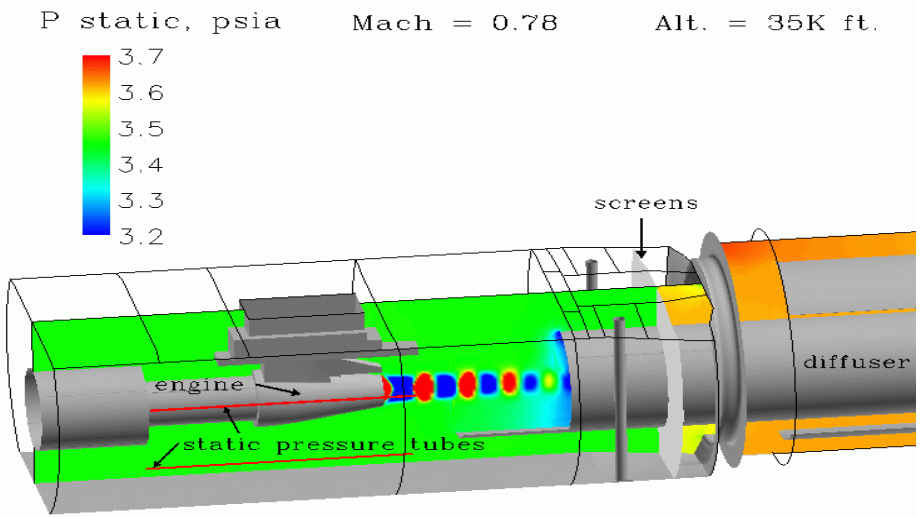


Development and evaluation of lethality and survivability technologies for FCS

Large Commercial Engine Test Simulation

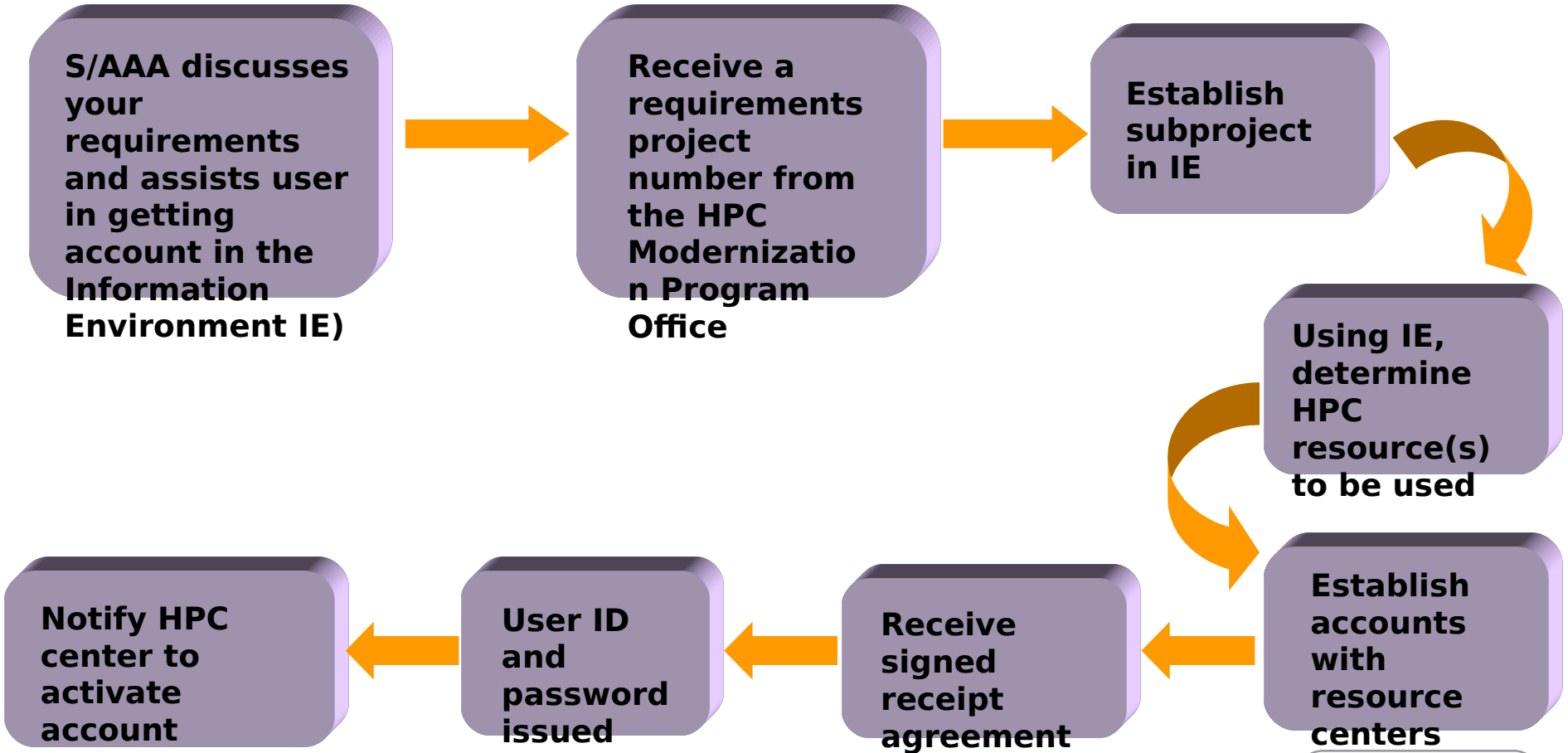
M.D. McClure, AEDC/Aerospace Testing Alliance, Arnold AFB, TN; Sponsor: Air Force

- Examines the AEDC test facility's Exhaust Gas Management System capability to provide an environment around the engine test article that does not adversely impact the engine thrust measurements
- Critical that the thrust measurement system be unaffected while the engine is operating
- CFD calculations used to verify that the static pressure gradients in the

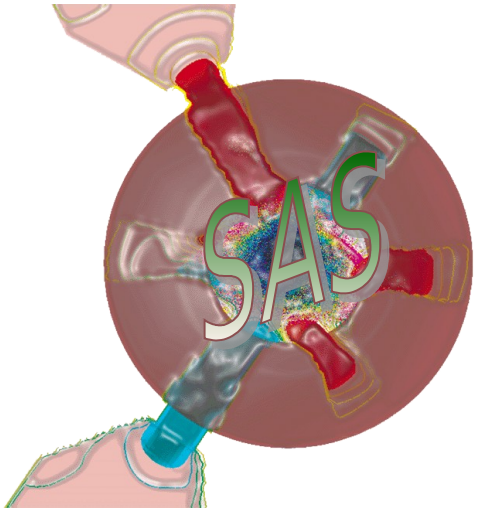


An analysis of this proposed test installation gives the test engineer confidence that the design will work as expected before any expensive hardware fabrication and assembly is done.

Getting Started
The Process


S/AAA discusses your requirements and assists user in getting account in the Information Environment IE)
Receive a requirements project number from the HPC Modernizatio n Program Office
Establish subproject in IE
Using IE, determine HPC resource(s) to be used
Establish accounts with resource centers
Receive signed receipt agreement
User ID and password issued
Notify HPC center to activate account

HPCMP Addresses T&E Needs



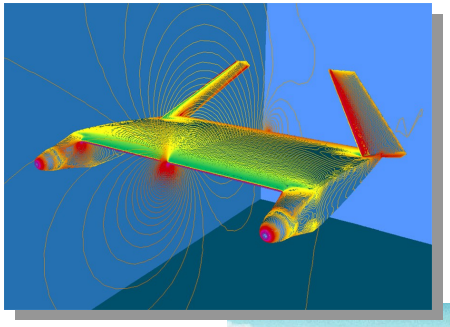
T&E Challenges

Storage
Latency
Security
Realism
Technology

HPC Modernization Program -- Essential tool for the Future

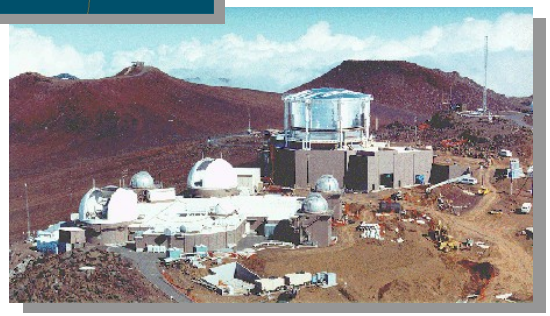
www.hpcmo.hpc.mil

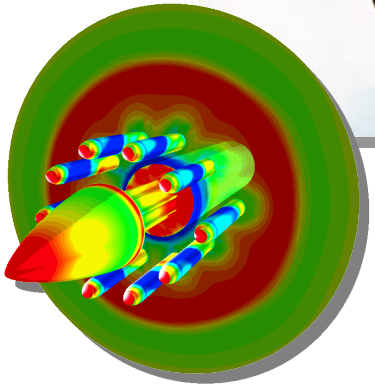
Micro Air



Joint Strike Fighter

Surveillance Systems

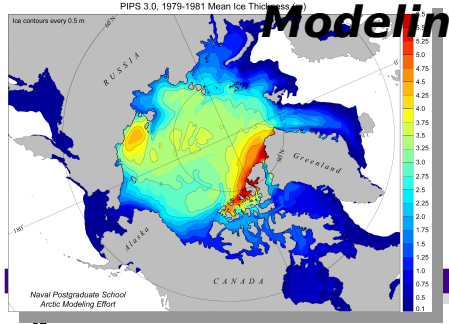




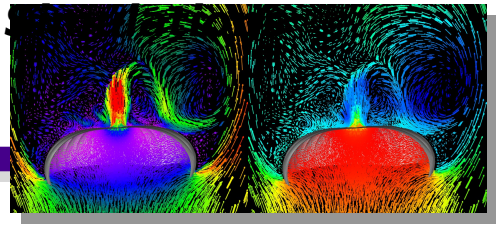
Smart Weapons Design

Unmanned Air Vehicle

Ocean Modeling



Parachute



Blast Protection

BACKUP

Potential Uses of HPC Resources for Test and Evaluation

Objective

Virtual electronic battlefield, a test bed where tactics, sensors and systems needed for network centric warfare applications can be evaluated and tested within a high resolution battlefield environment.

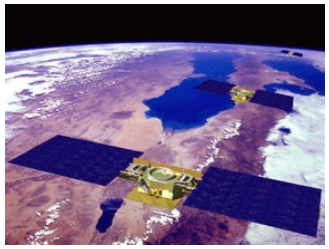
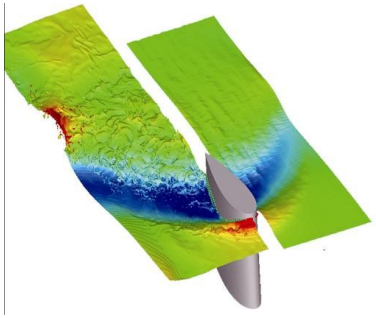
High performance tracking and fusion system to support a variety of operations at T&E ranges

Challenge

To develop efficient parallel FFT algorithms for extremely large data vectors

Keep system latency sufficiently short to permit its use within a control loop; creating a platform that is portable enough to deploy in any test environment

Potential Uses of HPC Resources for Test and Evaluation

	Objective	Challenge
	Stimulate proposed onboard processors under test in real-time through high performance modeling and simulation and real-time interfaces for Space-Based Radar…	Interface multi-teraflop cluster technology to embedded systems under test…
	Real time analysis and decision support for test and evaluation; augment human characterization of test data	Extracting knowledge in real time from raw engineering performance data
	Time-dependent hydrodynamic analysis of marine vehicles and their appendages and propulsors Capability to conduct virtual experiments of ship designs	Prohibitive disk storage requirements and download times;